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WIND DAM ELECTRIC GENERATOR AND METHOD

TO WHOM IT MAY CONCERN:

BE IT KNOWN THAT PAHL W. RICE, employee of the United States Government, citizen of the United States of America, resident of Jewett City, County of New London, State of Connecticut, has invented certain new and useful improvements entitled as set forth above of which the following is a specification:

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3 WIND DAM ELECTRIC GENERATOR AND METHOD
4

5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used
7 by or for the Government of the United States of America for
8 governmental purposes without the payment of any royalties
9 thereon or therefore.
10

11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 The present invention relates to generation of electrical
14 power utilizing wind and, more particularly, to systems and
15 methods for an increased efficiency wind power generator.

16 (2) Description of the Prior Art

17 At a time of both ever-increasing energy needs and non-
18 renewable petroleum products to meet those needs, now is the time
19 to consider the development and implementation of alternate
20 energy sources. Wind generation of electricity is not a new
21 idea; some believe the first wind generator was created by Poul
22 la Cour in 1891 to generate hydrogen for the gaslights in his
23 school. Since that time, a tremendous amount of engineering and
24 development has gone into wind generators.

1 Bentz' law (formulated by the German Physicist Albert Bentz
2 in 1919) states that you can only convert less than 16/27 (59%)
3 of the kinetic energy of the wind to mechanical energy using a
4 wind turbine. From research done in Denmark, a typical wind
5 turbine generator runs at about 20% efficiency. This is
6 primarily due to the effects of changing wind speed. For a
7 particular wind turbine generator, calculations are made, based
8 on the average wind speed for that area, to determine the optimum
9 turbine and generator size. The maximum efficiency (typically
10 about 40% to 50%) is reached at a particular wind speed. As the
11 wind speed increases, the efficiency decreases.

12 Previous efforts to solve problems related to the above are
13 described by the following patents:

14 U.S. Patent No. 4,017,205, issued April 12, 1977, to V. W.
15 Bolie, discloses a vertical axis windmill having a horizontal
16 base, preferably circular in configuration, sitting on the
17 earth's surface, a dome having a horizontal bottom spaced above
18 the base supported on a plurality of columns to provide an
19 annular space below the dome bottom, a conical baffle positioned
20 on the base below the dome, the conical axis being coincidental
21 with the vertical axis of the dome, the dome having a circular
22 roof orifice therein coaxial with the axis of the conical baffle,
23 a vertical shaft supported coaxially by the conical baffle and an
24 impeller affixed to the shaft and positioned in the dome circular
25 orifice. Wind blowing relative to the windmill causes a lifting

1 force by the aerodynamic effect of the dome, the wind passing
2 upwardly through the annular opening and upwardly through the
3 dome orifice, imparting rotational energy to the impeller. Power
4 using apparatus such as generators or the like may be attached to
5 the rotating vertical shaft. An alternate embodiment includes the
6 utilization of a plurality of vertical vanes between the base and
7 the dome, exterior of the conical baffle to more effectively
8 direct the flow of air upwardly through the dome orifice.

9 U.S. Patent No. 4,585,950, issued April 29, 1986, to A. M.
10 Lund, discloses multiple induction type generators drivingly
11 connected to an impeller. As wind velocity increases, the
12 generators are successively activated until all of the generators
13 are operating at a maximum wind velocity. As the wind velocity
14 decreases, the generators are successively de-activated until all
15 of the generators are inoperative below a minimum wind velocity.
16 Wind energy is more efficiently converted into electric power
17 where impeller RPM must be maintained substantially constant
18 under varying wind conditions to achieve the desired constant
19 phase of the AC output.

20 U.S. Patent No. 5,057,696, issued October 15, 1991, to R. N.
21 Thomas, discloses a vertical windmill employing aerodynamic lift
22 includes stators that form an omnidirectional diffuser and can
23 rotate out of the wind to reduce the destructive tendencies in
24 high winds. A braking mechanism included in the windmill uses
25 rotation of the airfoils to reduce the lift caused by the wind

1 and disengagement of the airfoils to reduce nearly all lift on
2 the airfoils. Centrifugal force is used to activate the brake in
3 high winds, both to slow the rotor speed and, in extreme winds,
4 to stop the rotor. A motor is provided to drive the windmill to
5 simplify controls and increase energy production.

6 U.S. Patent No. 5,518,362, issued May 21, 1996, to A. E.
7 Kivilammi, discloses a method and wind power station for the
8 utilization wind energy and transformation of wind energy into
9 electrical energy. The wind power station comprises several
10 rotors rotating by wind energy and connected to electricity
11 producing generators. From these rotors the wind stream is
12 directed also to a separate, main rotor to thereby maximize the
13 output from a given stream.

14 U.S. Patent No. 6,242,818, issued June 5, 2001, to R. H.
15 Smedley, discloses a vertical axis wind turbine having a
16 plurality of blades around its periphery and a pivotable door
17 associated with each blade. Each door has a pivot axis that is
18 inclined outwardly toward the bottom of the turbine so that
19 gravitational forces will pull the doors toward an open position.
20 The doors are designed to move toward a closed position to at
21 least partially block wind forces from the blades when the rotor
22 rotates at potentially damaging speeds. The turbine has mating
23 coils on the rotor and the support column to generate electrical
24 energy when the rotor rotates.

1 U.S. Patent No. 6,249,059, issued June 19, 2001, to N.
2 Hosoda, discloses a wind power device comprising a wind guide and
3 a twisted member in the wind guide. The wind guide is rotatable
4 around a vertical shaft so that a front opening of the wind guide
5 may always face the wind. The wind which comes into the wind
6 guide is guided around the twisted member and reaches to a blade
7 wheel, which actuates a generator via gears to create electric
8 power.

9 U.S. Patent No. 6,448,669, issued September 10, 2002, to D.
10 M. Elder, discloses a turbine used to convert wind or fluid
11 energy, and in some embodiments the kinetic energy of water, into
12 mechanical energy, more specifically, a long axis type of
13 vertical-axis turbine allowing large columns of air or water to
14 be harnessed. These devices differ from horizontal-axis
15 (propeller) type windmills or watermills which typically rotate
16 about a vertical axis in order that they may face directly into a
17 wind. The present invention is designed to be employed as a cost
18 effective alternate power source in any wind or water current
19 condition from a breeze to a gale wind, to a slow to moderate to
20 fast water currents. To increase the structural integrity, the
21 torque generating elements, namely, the rotor blades, are not
22 directly attached to the shaft but rather, they attach to the
23 round top and bottom rotor cage plates through which torque
24 forces generated can be transferred to the shaft. The unique
25 design of an open cover on the top of the wind or water turbine

1 allows wind or water from the direction above the turbine to be
2 harnessed. The top shield structure has created a calm wind or
3 water area between the shield and the top of the rotor cage that
4 helps reduce turbidity and greatly facilitates wind or water
5 exhaust from the system.

6 U.S. Patent Application Publication No. 2002/0070558,
7 published June 13, 2002, to K. Johann, discloses a windmill for
8 converting wind energy into electrical power and supplying it to
9 a power grid, comprising a blade assembly, a generator housing,
10 and a main shaft operatively coupled between the blade assembly
11 and generator housing. The generator housing contains a first
12 generator having a first generator output and a second generator
13 having a second generator output. A hydraulic strut supports the
14 generator housing and allows angular adjustment thereof. A
15 hydraulic pump selectively pressurizes the hydraulic strut to
16 effect adjustment thereof. A braking system is selectively
17 actuable to slow rotation of the main shaft. A flyweight assembly
18 and a four position speed sensing switch together detect
19 rotational speed of the main shaft, selectively connect the
20 generators with the main shaft, and selectively activate the
21 braking system and hydraulic pump as appropriate according to the
22 speed detected by the speed sensing switch.

23 The above patent applications do not describe a means for
24 utilizing multiple generators and/or a variable wind dam for
25 controlling windmill vertical rotor shaft rotational speed to

1 thereby provide a substantially constant frequency output along
2 with an increased efficiency wind power electrical generator.
3 The solutions to the above-described problems have been long
4 sought without success. Consequently, those skilled in the art
5 will appreciate the present invention that addresses the above
6 and other problems.

8 SUMMARY OF THE INVENTION

9 An object of the present invention is to provide an improved
10 windmill electrical power generator.

11 Another object of the present invention is to provide a
12 plurality of generators interconnected with the windmill in a
13 manner whereby the generating capacity thereof is controlled in a
14 manner to provide a substantially constant windmill shaft
15 rotational speed.

16 Another object of the present invention is to provide
17 moveable air foils operable for controlling the wind flow to
18 windmill blades in the power producing part of their rotation.

19 These and other objects, features, and advantages of the
20 present invention will become apparent from the drawings, the
21 descriptions given herein, and the appended claims. However, it
22 will be understood that above listed objects and advantages of
23 the invention are intended only as an aid in understanding
24 aspects of the invention, are not intended to limit the invention

1 in any way, and do not form a comprehensive list of objects,
2 features, and advantages.

3 Accordingly, the present invention provides a wind generator
4 for generating electricity in response to wind flow comprising
5 one or more elements such as, for instance, a vertical or
6 horizontal axis windmill comprising a shaft and a plurality of
7 blades secured thereto, at least two moveable air foils which
8 form an adjustable size opening for directing a selectable amount
9 of the wind flow into the plurality of blades, a base supporting
10 the at least two air foils, the base being rotatably mounted for
11 orienting the at least two air foils into the wind flow, a ring
12 gear mechanically affixed to the shaft, and/or a plurality of
13 generators arranged for mechanical interconnection with the ring
14 gear. The entire unit just described can also be set up
15 horizontally to minimize the overall height of the unit.

16 The plurality of generators may comprise moveable mechanical
17 elements operable for mechanically engaging and for disengaging
18 the plurality of generators with the ring gear. The wind
19 generator may further comprise a control operable for maintaining
20 a substantially constant rotating frequency of the shaft even as
21 a speed of the wind flow changes. This is accomplished by
22 selectively varying a generating power capability of the
23 plurality of generators connected to the shaft through the ring
24 gear. The control is preferably also operable for controlling
25 wind flow to the plurality of blades through the adjustable size

1 opening in coordination with generator power capability for
2 maintaining the substantially constant rotating frequency of the
3 shaft even as a speed of the wind flow changes.

4 In one embodiment, the plurality of generators may remain
5 mechanically connected to the ring gear and the control is
6 operable for controlling a stator current to thereby control the
7 generating power capability. In another embodiment, the wind
8 generator may further comprise moveable mechanical coupling
9 elements such that the control is operable for mechanically
10 coupling and uncoupling each of the plurality of generators from
11 the ring gear to thereby control the generating power capability.

12 The wind foils are positioned and shaped to direct the wind
13 flow substantially only to blades which are in a portion of a
14 rotation to be moving in the same direction of the wind flow and
15 to block wind flow to blades which are in a portion of the
16 rotation to be moving in the opposite direction of the wind flow.

17 A method for operating the windmill for generating
18 electricity comprises one or more steps such as, for example,
19 connecting the plurality of generators such that a generating
20 capacity thereof can be varied to thereby vary resistance to
21 rotation of the axis, mounting the one or more moveable wind
22 foils for controlling an amount of wind flow directed at wind
23 blades in a power producing portion of a rotation around the
24 axis, monitoring a rotational speed of the axis, and/or
25 controlling the generating capacity and a position of the

1 moveable wind foils responsively to the rotational speed of the
2 axis to maintain a substantially constant rotational speed.

3 The method may further comprise mounting a flywheel to the
4 axis to stabilize the rotational speed and/or may further
5 comprise providing a ring gear on the flywheel for
6 interconnection with the plurality of generators. The generating
7 capacity may be varied by engaging or disengaging a respective
8 rotor for each of the plurality of generators with respect to the
9 ring gear. The method may further comprise varying the one or
10 more moveable wind foils each time a respective of the plurality
11 of generators is engaged or disengaged with respect to the ring
12 gear.

13 In one embodiment, the method may further comprise providing
14 at least two wind foils which are relatively moveable with
15 respect to each whereby a variable opening is formed therebetween
16 for controlling the amount of wind flow directed at wind blades
17 in the power producing portion of their rotation around the axis.
18 The generating capacity may also be varied by controlling a
19 stator current for each of the plurality of generators.

20

21 BRIEF DESCRIPTION OF THE DRAWINGS

22 A more complete understanding of the invention and many of
23 the attendant advantages thereto will be readily appreciated as
24 the same becomes better understood by reference to the following
25 detailed description when considered in conjunction with the

1 accompanying drawings, wherein like reference numerals refer to
2 like parts and wherein:

3 FIG. 1A is a diagrammatic view showing a wind dam comprising
4 a windmill wherein the wind funnel structure is substantially
5 open to wind flow in accord with the present invention;

6 FIG. 1B is a diagrammatic view showing the wind dam of FIG.
7 1A with a windmill wherein the wind funnel structure is in the
8 process of closing to restrict wind flow in accord with the
9 present invention;

10 FIG. 1C is a diagrammatic view showing the wind dam of FIG.
11 1B with a windmill wherein the wind funnel structure continues to
12 close to restrict wind flow in accord with the present invention;
13 and

14 FIG. 1D is a diagrammatic view showing the wind dam of FIG.
15 1C with a windmill wherein the wind funnel structure is
16 substantially closed to restrict wind flow in accord with the
17 present invention.

18 FIG. 2 is a perspective view showing a vertically oriented
19 wind dam with a windmill and a variable opening wind funnel
20 structure in accord with the present invention.

22 DESCRIPTION OF THE PREFERRED EMBODIMENT

23 Referring now to the drawings, there is shown wind dam
24 generator 10 which uses wind as its source of power to generate
25 electricity for public use. As shown in FIG. 2, wind dam

1 generator 10 has an elongated cylindrical shape. Blades 12 may
2 be made of fiberglass-reinforced plastics or any other suitable
3 material and mounted in the center on an axle 14. On either side
4 of the blades 12, on the front end of wind dam generator 10,
5 which is oriented toward the incoming wind 15, are two wind
6 funnel air foils 16 and 18, forming the wind dam. In one
7 embodiment, both wind funnel air foils 16 and 18 are relatively
8 moveable in orientation with respect to each other and axle 14.

9 However, either air foil funnel structure 16 or 18 could be
10 fixed with the other air foil funnel structure being relatively
11 moveable, if desired. Thus, funnel structures 16 and 18 are
12 relatively moveable with respect to each other so they can be
13 opened or closed to moderate the amount of wind passing through
14 the generator (see FIG. 1A, FIG. 1B, FIG. 1C, and FIG. 1D).

15 As noted, air foils 16 and 18 form a funnel that guides the
16 wind to windmill blades 12. Preferably, air foil 18 may have an
17 internal wind blocking circumference 19 that covers some blades
18 12 to prevent counter forces acting on the blades which would go
19 against the direction of rotation as indicated by arrow 17.
20 Thus, the arc of internal wind blocking circumference 19 may
21 comprise about sixty to one hundred degrees of the rotational
22 circle. Flow of the wind against those blades covered by
23 internal wind blocking circumference 19 would have counter forces
24 produced on axel 14 if the wind were to encounter them. On the
25 other hand, the remaining blades which are not covered by

1 internal wind blocking circumference 19 are in the power
2 producing part of their rotation. By directing air flow onto
3 these blades, the power produced in axel 14 is maximized.

4 Air foil 18 at least would include guide surface 21 which
5 extends radially outwardly from the outermost reach of blades 12
6 to scoop out additional wind and direct that wind to the power
7 producing blades. Conceivably guide surface 21 may also be
8 sufficient to block the air flow significantly without the use of
9 blocking surface 19, if desired.

10 Air foil 16 may preferably be used as the other side of the
11 funnel to scoop in air from a large radius and direct the air to
12 the power producing blade as indicated in FIG. 1A. As necessary,
13 the opening through which the air flows between air foils 16 and
14 18 can be greatly restricted as indicated in FIG. 1B, FIG. 1C,
15 and FIG. 1D. As indicated, the two air foils 16 and 18 produce a
16 variable opening funnel which can selectively either introduce
17 air from a region of air with a diameter greater than the radius
18 of blades 12 which is preferably applied only to the power
19 producing blades, or can be narrowed to any extent including air
20 from a region of air much smaller than the diameter of the radius
21 of blades 12 for introduction preferably to the power producing
22 blades. Control 23 may be utilized to monitor axel rotational
23 speed for opening and closing air foils 16 and 18 as desired.

24 At the base of blades 12 is, in one embodiment, large gear
25 flywheel 20. Flywheel 20 serves two purposes; one is to limit

1 the change in speed due to wind gusts, and the other is to
2 provide a support for ring gear 28 which interconnects with
3 multiple generators, and if desired, allows multiple generators,
4 such as generators 22 and 24, to be mechanically
5 connected/disconnected to thereby come on and off line as the
6 wind speed changes. In a preferred embodiment, wind dam
7 generator 10 would typically comprise four to eight generators.
8 Mounting the generators on the ground allows use of much larger
9 generators than those that are mounted on the shaft as is used in
10 the prior art.

11 If engageable/disengageable mechanical interconnections are
12 utilized as in one embodiment of the invention, then generator
13 shaft 26 could be connected by a universal joint to thereby
14 permit raising and lowering shaft 26 for interconnection with
15 gear 28 of flywheel 20. As one possible alternative, generator
16 22 could be slidably mounted to thereby move gear 30 into
17 engagement with ring gear 28. Synchromesh gear arrangements, as
18 could be provided in various ways, would permit smooth engagement
19 and disengagement. As another possibility, the generators may be
20 connected through a clutch. In yet another embodiment, all
21 generators could remain connected mechanically through fly wheel
22 20 or by other mechanical connections and the engagement/
23 disengagement of the generator could be effected electrically by
24 controlling the stator current of each generator to thereby
25 control the physical resistance encountered by each generator

1 shaft 26, as discussed in more detail hereinafter. However the
2 generators are interconnected and operated, the generators are
3 preferably utilized as a means for maintaining a constant shaft
4 speed. Constant shaft speed results in a constant frequency
5 output of the power, which is desirable especially if power is
6 applied to a power grid.

7 Wind dam generator 10 is preferably mounted on controlled
8 rotating platform 32 that would keep the wind dam generator 10
9 pointing into the wind (see FIG. 2), preferably by automatic
10 control with control 23. Base 34 supports the entire structure.

11 One embodiment of a method of operation for wind dam
12 generator 10 is as follows; when the wind reaches a minimum speed
13 to provide the desired frequency of operation with airfoils 16
14 and 18 open, (typically 6 to 10 m.p.h.) the first asynchronous
15 generator, such as generator 24, would be connected to gear 28 on
16 flywheel 20. This would start producing the minimum rated amount
17 of electricity for the generator at the desired frequency of
18 operation, e.g., 50 Hz or 60 Hz. As the wind increases in speed,
19 airfoils 16 and 18 on either side of the blades would start to
20 close, to keep the generator turning at a constant speed (to
21 produce alternating current (AC) electricity at the constant
22 desired frequency). When the wind reaches a particular higher
23 speed, airfoils 16 and 18 on either side would open, allowing
24 more wind to enter the blades and, at the same time, another
25 generator, such as generator 22, would be mechanically connected

1 to the gear at the base of the unit. This process would continue
2 as the wind speed increases. As indicated above, preferably
3 from about four to eight generators would be available. The
4 airfoils would continue to close together until another threshold
5 was reached, then they would open and another generator would be
6 added. This process would use wind energy much more efficiently
7 than the current large wind blade style. It would be able to
8 produce electricity at a lower wind speed, and continue to
9 efficiently extract energy from much higher wind speeds. The
10 frequency of electricity produced would be kept at a more
11 consistent value while the amperage increased or decreased along
12 with the wind. The order of implementation for the generators
13 would preferably be in a circular queue. The first would be
14 added, then the second, then the third, as the wind increases.
15 When the wind starts to decrease, the first generator would be
16 removed. If the wind increased, the fourth generator would be
17 implemented. This would continue in a circular fashion until it
18 came back around to the first generator. This process would
19 ensure that all generators would statistically get the same
20 amount of use and that a generator could be taken off line for
21 maintenance without affecting power generation. It also
22 optimizes the efficiency of the unit. Cooling would be done at
23 the same rate as the addition and deletion of generators to
24 implement only the cooling that is required. The optimum number
25 of generators for the system would be determined through wind

1 characteristics of the location of the wind dam generator 10 and
2 through experimentation.

3 Control 23 may be utilized with suitable programming for
4 monitoring wind speed, and the number of generators, and the
5 opening of air foils 16 and 18, and for orienting the air foils
6 towards into the wind direction by rotating base 34. Thus,
7 control 23 could be programmed to monitor axel rotational speed
8 and adjust the other factors accordingly in a feedback circuit.

9 As the wind speed increased, so would the number of
10 generators. Instead of wasting the extra energy of the higher
11 wind speeds, it would be collected by another generator. The
12 wind dam generator 10 would not be limited by the power rating of
13 a single generator. It would be able to maintain a 30% to 40%
14 efficiency over a broader range of wind speeds.

15 In another embodiment, all generators would remain connected
16 with respect to flywheel gear 28 or other gearing. Initially,
17 the stator current in each generator would be zero or near zero
18 and the generators effectively disconnected because with zero
19 current, and assuming no magnetic residual, there is no
20 resistance except friction resistance. The additional rotating
21 shafts would also provide a flywheel effect as discussed above
22 for reducing minor variations in shaft speed. With the wind
23 foils open, once the shaft came up to the desired frequency of
24 rotation, then stator current would be applied to one or more
25 generators thereby controlling the torque or force required to

1 rotate the generator shaft, and the force acting against rotation
2 of axel 14. In this case, control 23 may comprise a feedback
3 system which would then control the stator current based on the
4 rotational speed of axel 14. As axel speed starts to drop, the
5 stator current would be reduced to permit easier rotation of axel
6 14 thereby maintaining the rotational frequency. As axel speed
7 starts to rise, an increase in stator current would increase the
8 rotational resistance to maintain the shaft rotational speed.
9 The current output would vary accordingly. If the wind becomes
10 too high after all generators are operating at maximum, then air
11 foils 16 and 18 would begin closing to reduce the wind to
12 maintain the frequency. Items 36 through 38 may symbolically
13 represent sensors such as wind direction sensors, air speed
14 sensors, air foil position sensors, rotatable base 32 position
15 sensor, axel rotation speed sensor, generator sensors, other
16 desired sensors and actuators, and could also represent
17 additional generators that may preferably be utilized.

18 The advantages of the present invention include a smaller
19 footprint than the standard large blade generators, and a much
20 more intelligent, efficient generator that could produce more
21 power over a broader range of wind speeds. As another advantage,
22 the entire wind dam generator can be built with either a vertical
23 or horizontal shaft or actually a shaft with any orientation. If
24 built with a horizontally oriented shaft, for instance, the
25 overall height of the unit can be greatly minimized. Moreover, a

1 horizontal blade shaft could be very long, but the unit would
2 still have a minimal height due to the fact that the entire unit
3 is on its side. Therefore, the present invention may be used in
4 places where height is an issue and in places where height is not
5 an issue.

6 It will be understood that many additional changes in the
7 details, materials, steps and arrangement of parts, which have
8 been herein described and illustrated in order to explain the
9 nature of the invention, may be made by those skilled in the art
10 within the principle and scope of the invention as expressed in
11 the appended claims.